Spatial estimates of temperature and precipitation normals for the Canadian Great Plains

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ABSTRACT

Results of the development of regional spatial climatic equations, used to compute monthly and annual normals of precipitation, maximum and minimum air temperatures for a 10 km x 10 km Universal Transverse Mercator grid square network covering the land mass area of the Canadian Great Plains Region, are presented. In developing the temperature spatial climatic equation the Great Plains area was separated into a southern and northern region delineated by latitude 55°N. Separate regional temperature equations were developed for each of these two regions. In developing the precipitation spatial climatic equations the southern region below 55° latitude was further subdivided into a western and eastern region with separate precipitation equations derived for each region. All equations, developed by step-wise multiple regression of climatic data observed at meteorological stations in the study area on physiographic characteristics computed for the vicinity of these stations, are significant at the one percent level.

Monthly and annual precipitation, and maximum and minimum air temperature normals for a 10 km x 10 km grid square network covering the entire Great Plains Region of Canada, based on these equations, have been generated. These derived data have been stored in the Agriculture Canada Capability Inventory Data Bank of Canada and are available on request from either the Land Use and Evaluation or the Agrometeorological Sections of the Land Resource Research Institute.

Foreword

Agroclimatic resource analysis has provided basic input to soil and climate inventories at the macroscale or national level. The detail and scale of this work could at best present an overview of Canada's soil and climate conditions, but this type of information is now inadequate in support of land use and evaluation studies at the mesoscale or regional level. The climatological station network maintained by the Atmospheric Environment Service of Canada although serving many users, cannot provide the spatial distribution of climatological data as required for many applications useful to agriculture. New techniques for the spatial interpolation of local or on-site climatological records must therefore be explored, including the use of satellite observations, mobile surveys and statistical approaches.

This publication describes the analysis undertaken for the development of spatial climatic equations which have been used for estimating the monthly and annual normals of temperature and precipitation for a 10 km^2 grid square network covering the Canadian Great Plains Region. The Atmospheric Environment Service of Canada provided the necessary climatological data files; data processing and research staff of the Agrometeorology Section of the Land Resource Research Institute contributed through computerization of data preparation and development of agroclimatic analysis techniques; and the Shawinigan Engineering Company under a research contract provided the physiographic characteristics and spatial climatic equations used in computing the climatic normals.

Earlier publications in the "blue" technical bulletin series presented techniques and data of interest to a wide group of users of various derived climatological information. This report should be equally useful to those concerned with the evaluation of climatic resources at the mesoscale level in support of crop productivity, land capability and farm management studies. The derived temperature and precipitation data on a grid-square basis are now available in the Land Capability Inventory Data Bank of the Land Resource Research Institute, Agriculture Canada.

It gives me great pleasure to introduce this report and at the same time to thank all persons who contributed in various ways to the development of this new type of climatological information.

Wolfgang Baier

1.0 Introduction

The data analysis described in this bulletin was undertaken in order to provide estimates of monthly normals of temperature and precipitation for the Canadian Great Plains Region at the mesoscale level. It forms part of the Agricultural Land Capability Inventory Data Bank which is currently being developed to meet the needs of scientists and others concerned with evaluating the suitability of land for agricultural productivity.

To facilitate classification of land capability as determined by soil and climate there is a need for an objective procedure for estimating the climate at any point in the absence of actual measurements. The spatial distribution of climatic stations is usually inadequate for mesoscale analysis because of the difficulty in interpolating between measurement points, particularly in areas where few stations exist. Hopkins (1965), (1967) recognized this problem in the Canadian Great Plains area and developed a regression technique to compensate for the inadequate station network relating the normals of mean, maximum and minimum daily air temperatures to latitude, longitude and elevation. Williams (1969), (1971a), and Williams et al. (1980) subsequently have used this technique with satisfactory results for assessing the agroclimatic resources for maturing wheat and barley in this area. At the same time Solomon (1966) and Solomon et al. (1968) developed a computerized grid square network technique to calculate spatial estimates of precipitation, temperature and run-off distribution from physiographic data for Newfoundland.

Recognizing the possible usefulness of the Solomon procedure for developing a computerized data bank for land evaluation purposes a pilot study was undertaken in Ontario and Saskatchewan during 1977 (Stewart et al., 1980) to examine the feasibility of using their procedures for estimating various climatic elements. Results provided 39 spatial climatic equations for estimating monthly and annual normals of precipitation, maximum and minimum air temperatures. These were subsequently used with satisfactory results to generate spatial estimates of temperature and precipitation normals representing a 5 km x 5 km and 10 km x 10 km grid square network in Southern Ontario and Southern Saskatchewan-Manitoba, respectively. All physiographic and derived climatic data have been incorporated into the Agricultural Land Capability Inventory Data Bank of Canada currently being developed by Agriculture Canada.

A similar project was begun in 1978 to generate these normals for a 10 km x 10 km grid square network covering the entire Great Plains Region of Canada. This bulletin outlines the results obtained for the Canadian Great Plains study describing:

a) the preparation and analysis of the climatic and physiographic data;
b) the development of the spatial climatic equations using these data to estimate the monthly and annual normals of temperature and precipitation; and

c) the computer file record format in which all grid square identification, physiographic and climatic information has been stored in the data bank.

2.0 Study Area

The area known as the Canadian Great Plains ranges from the Canadian/U.S. border to the Arctic Ocean and is bound by the Rocky Mountains in the west and the Canadian Shield in the east. The approximate geographic limits as outlined by Hopking (1967) together with those used in the present study are shown in Figure 1.

3.0 Data

The spatial climatic equations, developed in this study, were derived by regression analysis of climatic data and physiographic features. Data available for the Great Plains study region are outlined below.

3.1 Physiographic Data

Physiographic characteristics of the Canadian Great Plains region, obtained from Shawinigan Engineering Co. (Shawinigan, 1970), were provided in a 10 km x 10 km grid square network from referenced to the 1:250,000 scale National Topographic System Maps of Canada. Data available for each grid square is listed in Table 1.

A grid square within the study area is located by the Universal Transverse Mercator (UTM) coordinate system. This system divides a projection of the earth's surface into 6^{o} longitudinal zones. Each 10 km x 10 km grid square within a zone is identified by a coding consisting of two letters and two numbers. The letters identify the SW-corner of a 100 km x 100 km grid square within the zone. The numbers identify the SW corner of the particular 10 km x 10 km grid square within the larger 100 x 100 km grid square.

3.2 Climatic Data

In the regression analysis the climatic data used were the monthly and annual normals of precipitation and maximum and minimum daily air temperatures. These normals were obtained from the Atmospheric Environment Service (Environment Canada) and represent the period 1941-70. Table 1 summarizes the number of stations used in the analysis.

In computing the normals the Atmospheric Environment Service (AES) has adjusted the averages at those stations with less than 30 years records (short-period stations) to make them comparable with stations with full period records using the procedures of Aston and Kendall (1972). Evaluation of this procedure by the AES has been undertaken for several long-term stations using partial record periods and comparing the results with

test data. In almost all cases the estimated normals for temperature were within ±0.3°C of the true normal. For precipitation, however, the results were more erratic. Despite this, these data were used in this study since no method has been found to improve the currently published estimates.

In the regression analysis those stations with less than 10 years of record or located in the mountains of British Columbia and Alberta were discarded. Of the remaining stations 10 to 12 percent were set aside for validation. These stations, selected randomly throughout the study area, were not used in the development of the regional relationships. A summary of the numbers of stations used in the regional calibration analyses and validation tests is given in Table 1. In the following discussion "calibration" refers to those stations used in deriving or developing the spatial climatic equations, whereas, "validation" refers to those stations used in testing or evaluating the derived equations. The number of stations varies from month to month because some stations in the more remote locations are only operated seasonally.

4.0 Regional Analysis

4.1 Methodology

The methodology selected for developing the regional equations for estimating the climatic normals is essentially the same as that set out by Shawinigan (1977).

A stepwise multiple regression package which selects the sequence of independent variables by an improvement of explained variance criterion was used to derive the spatial climatic equations. This package, developed by IBM, operates on the Modified Doolittle method. Details of the method are outlined by Shawinigan (1977), and Bennett and Franklin (1954).

All stations selected for the analysis were assigned specific grid square locations. The physiographic characteristics of these grid squares are considered to be representative of the stations with one exception: the elevation selected was the actual elevation of the station and not the average elevation of the square. The physiographic characteristics selected as independent variables for the regression analysis are presented in Table 2. In the analysis land use/land cover parameters (percent area of lakes, forest, swamp, urban areas, glaciers, etc.) were not considered as independent variables. Although these parameters have some influence, the areal extent of this effect cannot be ascertained precisely. Consequently, it is assumed that their influence is limited to the particular square in which the climatic station is located.

It should also be noted in Table 2, that in the precipitation analysis some of the physiographic factors were combined to provide supplementary independent variables. The inclusion of these supplementary variables was undertaken in response to the results of the Shawinigan (1970) study. In this study it was found that their inclusion reduced both the number of physiographic variables required and the error in the precipitation normal estimates.

After derivation of the spatial climatic equations, using the station calibration sample, two tests were performed to evaluate their accuracy and spatial independence. In the first test the derived equations are used to calculate estimates of the climatic normals for the validation station sample. The computed values are then compared statistically with the measured or recorded values. On average, the standard error of estimate (difference between generated and actual station normals) for the validation sample should be similar to that of the calibration sample for the derived equations to be applicable to the study area. The second test evaluates the spatial independence of the derived equations by insuring that they have been derived for a statistically homogenous region. This test is performed visually by mapping the residuals (or errors of estimates) of both the calibration and validation samples. The errors (positive and negative) should be well distributed over the test area. If any significant cluster of positive or negative errors appear, these areas are isolated (or regionalized) and analyzed separately.

4.2 Results of Temperature Analysis

Derivation of the regression equations for the temperature normals involved several attempts directed at two aspects. The first, involved identification of the combination of independent variables which provided the best temperature normal estimates. The second, was the determination of homogeneous regions where the equations were applicable.

Since the independent variables to be used in the analysis had already been defined in previous studies (Shawinigan, 1970) this problem was solved through the process of elimination by arbitrarily selecting various combinations of independent variables and selecting the combination giving the least error. To improve the relationships, a further logarithmic transformation of the independent variables was also attempted. Results of this showed the transformed data to be less accurate then the data in its original state. For precipitation, however, the transformed data was of slightly better quality and this data was used in the analysis.

Initial regression equation development for the entire study area revealed a definite increase in the error of estimate with higher latitudes. The equations were heavily weighted toward the southern portion of the study area, due to the large difference in station densities between the southern and northern parts. As a result, the study area was split into a northern and southern region at latitude 55^{o}. The results, both from the point of view of validation and spatial homogeneity of the errors, were satisfactory and no further regionalization was undertaken. The regions were designated as "Region 1" for that part of the study area located north of 55^{o} latitude and "Region 2/3" for the southern area located below 55^{o} latitude. The 2/3 designation stems from the precipitation analysis discussed in Section 4.3 where the southern region was further split into a western (Region 2) and an eastern region (Region 3).

Derived spatial climatic equations and associated statistical summaries for each region for the monthly and annual normals of maximum and minimum daily air temperature are listed in Tables 3 and 4, respectively. As shown, except for minimum daily temperature from August to November in Region 2/3, correlation coefficients are all in excess of 0.8. The standard errors of the estimate for the temperature normals vary from 0.4°C (Region 2/3, October minimum) to 1.5°C (Region 1, January minimum). This large variation does not necessarily imply that some equations fit the data better than others. In fact most of the equations have comparable levels of significance. This variation only implies that there is more spatial variation in the temperature normals in certain months than in others which appears to be at a maximum in January and a minimum in September for both the maximum and minimum daily temperature normals in both regions.

Tables 6A and 6B outline the results of the temperature analysis in terms of errors for the calibration and validation samples. As shown, the errors in the validation sample are not significantly different from those of the calibration sample. This indicates that the equations are stable over the region of applicability.

The variations in the errors in regional estimates with latitude are presented in Table 7. In general the values show that the temperature errors increases from south to north. Above latitude 64° there may be a larger error than indicated due to the small number of stations in this region.

4.3 Results of Precipitation Analysis

As mentioned above, in the analysis of precipitation it was found that a logarithmic transformation of the actual precipitation normals led to slightly better regional estimates. This was particularly evident in the far north.

The study area was initially analyzed as a single region and then as two regions divided by 55° latitude. The analysis of the southern region showed that the equations tended to consistantly overestimate in the western portion, especially in the vicinity of Cypress Hills, while underestimating in the eastern portion. A simple regionalization was undertaken since the extent and location of these over and under estimations, although varying from month to month, was consistantly in an east-west direction. This consisted of separating the southern portion of the study area into a western region (Region 2) and an eastern region (Region 3), as seen in Figure 1, by a line connecting the point longitude 113°25', latitude 55°00' with the point longitude 105°15', latitude 49°00'. This boundary was selected by visual inspection of mapped results displaying the standard errors of estimates of the normals for each station. Subsequent analysis for each of these regions showed that the clustering of the standard error of the estimates, observed in the errors in the precipitation normals for the southern region as a whole, had been eliminated and no further regionalization of the data was undertaken.

The regression equations obtained for the precipitation normals and statistical summaries for each are listed in Tables 5A, 5B and 5C for the three regions. It is quite evident that most equations have much lower correlation coefficients in comparison to those for the temperature regressions. This is attributed to two reasons including the inherent errors in measuring precipitation accurately, and the generally greater local variability in precipitation receipt.

The standard errors of estimates are a measure of both the goodness of fit of the regressions and the spatial variability of precipitation. Spatial variability increases from winter to summer as does the amount of precipitation. In order to assess the goodness of fit of the equations, the standard errors of the estimate have been expressed as a percentage of the mean precipitation normal of the region. These ratios as detailed in Table 5 vary from 10 to 23 percent and 7 to 10 percent of the mean monthly and annual precipitation, respectively.

The derived spatial climatic equations for estimating the precipitation normals for each region are listed in Tables 5A, 5B and 5C, respectively. It is important to note that these equations do not estimate the precipitation normal itself, but the common logarithm of the precipitation normal in millimeters.

The standard errors of estimate of the precipitation normal, together with the maximum errors encountered in each region appear in Table 8A for the calibration sample (units are in mm of precipitation); Table 8B presents the results of the validation samples and the variations in the errors with latitude are given in Table 8C.

Estimates of the monthly and annual normals of precipitation, maximum and minimum air temperatures using the derived spatial climatic equations, listed in Table 3, 4 and 5 representing the 1941-70 period, were calculated for each 10 km x 10 km grid square covering the Canadian Great Plains. For each grid square the location, physiographic information, and all precipitation and temperature estimates have been recorded on computer magnetic tape; one file record per grid square. The structure and format of the computer files are given in Table 9.

Due to the massive amount of information contained in the above, to facilitate easy retrieval, the data bank has been subdivided into 18 files. Each file corresponds to one of the 18 National Topographic System 1:1 million scale topographic map sheets covering the Canadian Great Plains Region as listed in Appendix 10. These files have been stored in the Agriculture Canada Land Capability Inventory Data Bank and are available on request from either the Land Use and Evaluation or Agrometeorological Section of the Land Resource Research Institute.

5.0 Summary and Conclusion

The grid square climatic information generated from derived spatial climatic equations for the Great Plains Region was undertaken as an aid for those users requiring more spatially precise information at the mesoscale level than currently available from the AES station network.

Computed monthly temperature normals are for the most part within ±1°C of observed values at test stations in the southern part (below 55° latitude) of the study area increasing to ±2°C in the more northerly region (above 55° latitude). Precipitation values are somewhat more in error, however, averaging ±15 to 20 percent of observed data. This is primarily the result of the large variability in actual precipitation values observed in the study area.

It is hoped that the data will prove useful to those involved in land evaluation, crop productivity and agroclimatic resource assessment at the mesoscale level. Before utilizing the data, however, it should be noted by the user that there are limits in aerial extent or scale to which these data can be applied. It is recommended that these data not be used in studies involving spatial mapping scales of less than 1:1 million (i.e. 1:500,000 or 1:50,000). This stems from the fact that the derived spatial climatic equations were developed from the mesoscale climatic station network in conjunction with meso and macroscale physiographic characteristics involving the Great Plains Region as a whole. At mapping scales of less than 1:1 million, the local topographic and physiographic characteristics become very prominant in their influence on the temperature and precipitation distribution. Hence, the large scale physiographic features used in the development and application of the spatial climatic equations may not be very representative of those areas containing highly variable local spatial features. The spatially derived climatic data in this instance may be very inaccurate and application of these data to specific user problems could lead to erroneous results and interpretations.

The spatially derived temperature and precipitation normals in this study were devised and are best suited for mesoscale applications with general overview purposes in mind. For this reason care should be exercised on the part of the user in avoiding the temptation to extract more spatially detailed information than can be obtained from 1:1 million scale maps.

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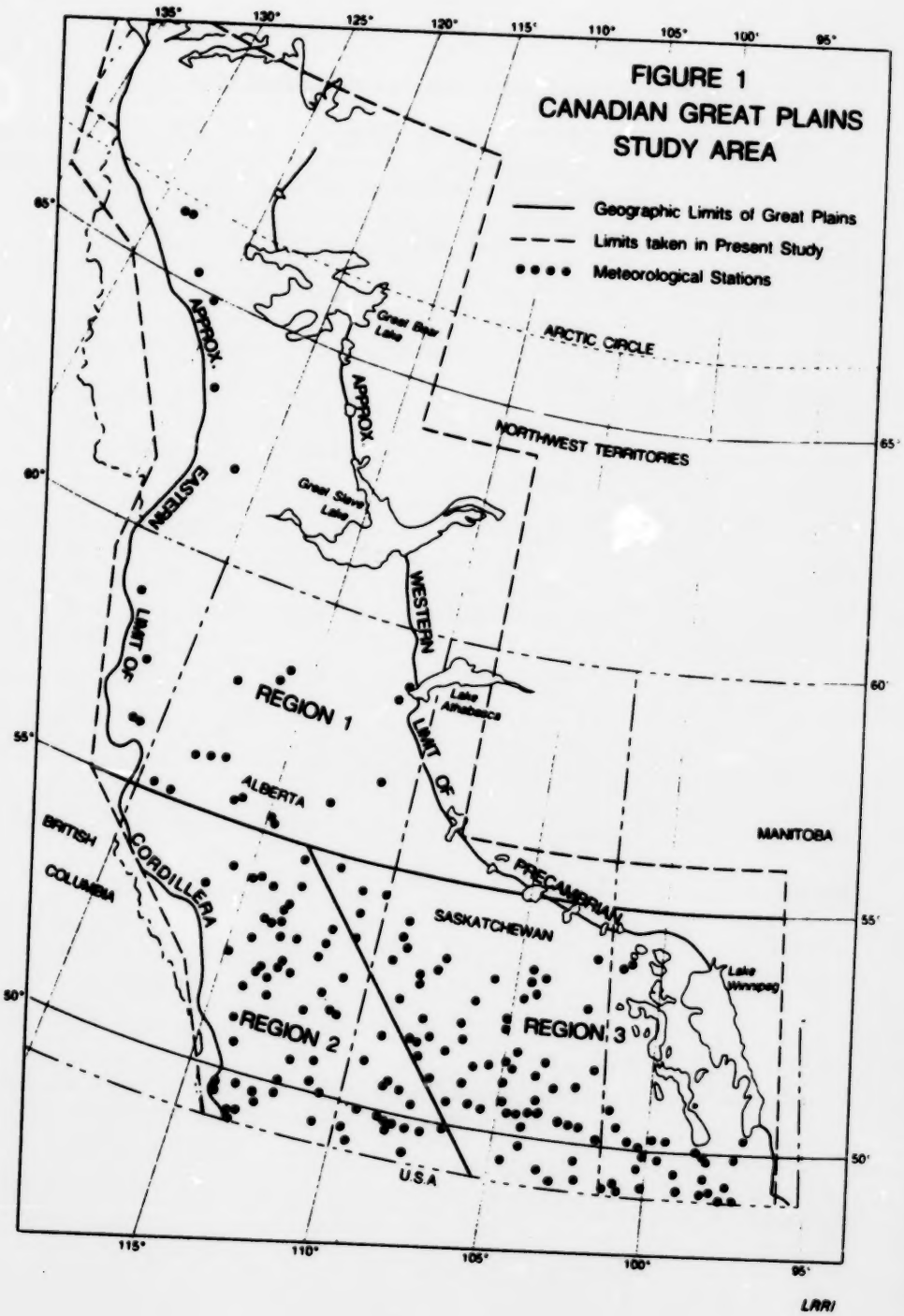
FIGURE 1
CANADIAN GREAT PLAINS
STUDY AREA
Geographic Limits of Great Plains
Limits taken in Present Study
Meteorological Stations
135°
130°
125°
120°
115°
110°
105°
100°
95°
65°
60°
55°
50°
ARCTIC CIRCLE
NORTHWEST TERRITORIES
APPROX. EASTERN LIMIT OF
APPROX. WESTERN LIMIT OF
Great Bear Lake
Great Slave Lake
Lake Athabasca
REGION 1
REGION 2
REGION 3
ALBERTA
SASKATCHEWAN
MANITOBA
BRITISH COLUMBIA
CORDILLERA
PRECAMBRIAN
Lake Winnipeg
USA
LRRI

TABLE 1

SUMMARY OF METEOROLOGICAL STATIONS

AVAILABLE FOR REGIONAL ANALYSIS

	Temperature			Precipitation		
	Calibration	Validation	Total	Calibration	Validation	Total
January	321	39	360	389	40	429
February	321	39	360	389	40	429
March	321	39	360	389	40	429
April	325	39	364	398	41	439
May	371	44	415	458	46	504
June	383	46	429	461	49	510
July	383	46	429	461	49	510
August	383	46	429	461	49	510
September	372	46	418	456	49	505
October	343	40	383	412	41	453
November	324	39	363	389	40	429
December	324	39	363	389	40	429
Annual	321	39	360	389	40	429

TABLE 2

PHYSIOGRAPHIC CHARACTERISTICS SELECTED AS INDEPENDENT VARIABLES IN CLIMATIC REGIONAL REGRESSIONS

Variable	Description	Unit in Regression Equations
X 1	Column No. of grid square (Langitude Index)	
X 2	Row No. of grid square (Latitude Index)	
X 3	Meteorological station elevation	m_4 x 10
X 4	Slope of grid square	$m/10^4 m$
X 5	Distance to sea in north direction	km x 10
X 6	Distance to sea in north west direction	km x 10
X 7	Distance to sea in west direction	km x 10
X 8	Distance to sea in south west direction	km x 10
X 9	Barrier height in north direction	m x 10
X 10	Barrier height in north west direction	m x 10
X 11	Barrier height in west direction	m x 10
X 12	Barrier height in south west direction	m x 10
X 13	Shield effect in north direction	m x 100
X 14	Shield effect in north west direction	m x 100
X 15	Shield effect in west direction	m x 100
X 16	Shield effect in south west direction	m_3 x 100
X 17	Regional slope in north east direction	$m/10^3 m$
X 18	Regional slope in east direction	$m/10^3 m$
X 19	Regional slope in south east direction	$m/10^3 m$
X 20	$(X\ 3)^2/100$	
X 21	$(X\ 17)^3_3$	
X 22	$(X\ 18)^3_3$	
X 23	$(X\ 19)^3_3$	
X 24	$(X\ 6)^2/1000$	
X 25	$(X\ 11)^2_2/1{,}000{,}000$	
X 26	$(X\ 13)^2_2/1000$	
X 27	$(X\ 14)^2_2/1000$	
X 28	$(X\ 9)^2/1{,}000{,}000$	
X 29	$(X\ 12)^2/1{,}000{,}000$	
X 30	X 8 x X 17	
X 31	X 7 x X 18	
X 32	X 6 x X 19	

NOTE: Variables 1 to 16 were used in temperature regressions. Variables 1 to 32 were used in precipitation regressions.

TABLE 3A

REGION 1 - REGIONAL SPATIAL CLIMATIC EQUATIONS FOR MAXIMUM DAILY AIR TEMPERATURE (ABOVE LATITUDE 55°)

JAN. = -24.29 + 7.621E-04 X3 - 4.894E-03 X5 -9.497E-06 X15

FEB. = -24.36 + 8.65E-03 X6 -2.414E-02 X1

MAR. = -20.76 + 1.325E-02 X5

APR. = -6.84 + 1.7E-02 X5 -1.141E-03 X3 -2.787E-03 X8

MAY = 1.88 - 2.589E-02 X5 - 7.21E-04 X3 -7.378E-2 X6 - 1.093E-05 X16

JUNE = 16.06 + 1.526E-02 X5 -6.831E-04 X3 + 1.928E-03 X6 +7.205E-06 X15 -6.717E-04 X7 -3.751E-05 X14 -4.834E-01 X1 -6.895E-06 X16

JULY = 52.11 -1.287E-01 X2 -6.998E-04 X3 -4.092E-02 X1 +6.217E-06 X15 -1.861E-05 X14 -1.986E-03 X8

AUG. = 44.17 - 1.117E-01 X2 -2.373E-03 X3 -2.126E-03 X8 +5.562E-06 X15 -2.414E-02 X1 -1.006E-05 X14

SEPT. = 6.99 + 9.917E-03 X5 -6.924E-04 X3 -1.524E-03 X8

OCT. = 17.51 -9.35E-02 X2

NOV. = 17.24 +6.017E-03 X6

DEC. = -21.92 - 3.681E-03 X6 -6.687E-06 X15 +6.55E-04 X3

ANN. = -7.17 + 9.383E-03 X5

NOTE: 1. Read 7.621E-04 X3 as $7.621\ 10^{-4}$X3

2. Temperatures are in (°C) and physiographic characteristics are in the units indicated in Table 2.

3. The independent variables (physiographic parameters) in the above equations appear in the order they were selected by step-wise regression analysis.

Reg. Eq. for	No. of Obs.	Mult. Corr. Coeff.	Standard Error Deg. C
Jan.	44	0.962	1.4
Feb.	44	0.989	1.1
Mar.	44	0.982	1.3
Apr.	44	0.982	1.2
May	66	0.960	1.3
June	70	0.932	1.1
July	70	0.939	0.9
Aug.	70	0.960	0.7
Sep.	65	0.977	0.7
Oct.	46	0.986	0.8
Nov.	44	0.971	1.3
Dec.	44	0.966	1.4
Ann.	44	0.985	0.8

TABLE 3B

REGION 2/3 - REGIONAL SPATIAL CLIMATIC EQUATIONS MAXIMUM DAILY AIR TEMPERATURES (BELOW 55° LATITUDE)

JAN. = -25.96 +2.645E-2 X14 -5.175E-2 X5

FEB. = -0.64 +1.753E-2 X14 -1.328E-3 X10 -6.129E-2 X02 -3.191E-2 X8

MAR. = 10.31 +1.744E-2 X14 -9.678E-3 X5 -5.056E-3 X3 -1.187E-3 X10 -2.422E-2 X8 -1.045E-3 X11 -5.792E-2 X2

APR. = 31.74 +3.779-3 X6 -6.741E-3 X7 -6.607E-3 X3 -5.562E-2 X1 -8.276E-2 X2

MAY = 48.33 +1.328E-2 X4 -1.590E-3 X6 -7.900E-3 X3 -8.057E-2 X1 -1.022E-1 +3.001E-3 X16 -1.132E-2 X14 +6.682E-4 X10

JUNE = 36.08 -8.430E-3 X3 +4.991E-3 X6 -6.381E-4 X12 -2.668E-2 X1 -6.090E-2 X2

JULY = 43.17 +5.452E-3 X16 -9.032E-2 X2 -7.577E-3 X3 -4.464E-2 X1

AUG. = 43.61 -1.143E-1 X2 -8.351E-3 X3 -1.201E-3 -2.812E-2 X1

SEPT. = 38.56 -1.017E-1 X2 +1.344E-2 X4 +9.859E-5 X10 -7.22E-3 X3 -5.0E-2 X1 +2.779E-3 X16

OCT. = 34.36 -8.275E-4 X6 -5.943E-3 X3 -3.308E-4 X14 -1.119E-1 -5.191E-2 X1

NOV. = 11.28 -9.617E-4 X6 +1.146E-2 X14 -9.778E-2 X2 -3.768E-2 X8 -4.393E-3 X3 -9.167E-4 X10 +3.184E-3 X16

DEC. = -2.31 +1.532E-2 X14 -8.678E-2 X2 -2.390E-2 X8

ANN. = -1.54 +3.138E-2 X6 +1.267E-2 X14 -3.221E-3 X3

NOTE: See Notes on Table 3A.

Reg. Eq. for	No. of Obs.	Mult. Corr. Coeff.	Standard Error Deg. C
Jan.	277	0.955	0.9
Feb.	277	0.964	0.8
Mar.	277	0.939	0.7
Apr.	281	0.928	0.5
May	305	0.943	0.4
June	313	0.962	0.5
July	313	0.964	0.6
Aug.	313	0.968	0.6
Sept.	307	0.966	0.4
Oct.	297	0.966	0.4
Nov.	280	0.977	0.4
Dec.	280	0.967	0.8
Ann.	277	0.939	0.5

TABLE 4A

REGION 1 - REGIONAL SPATIAL CLIMATIC EQUATIONS FOR MINIMUM DAILY AIR TEMPERATURE NORMALS (ABOVE 55° LATITUDE)

JAN. = -26.98 +2.452E-05 X14 -7.692E-06 X15 -1.827E-02 X2

FEB. = -17.94 -2.809E-04 X3 +4.974E-03 X5 +2.462E-05 X14

MAR. = -30.27 +5.983E-03 X5 +2.503E-04 X10 +5.673E-04 X3

APR. = -21.19 +1.179E-02 X5

MAY = -8.16 +1.544E-02 X5 -5.195E-03 X6 -6.4E-05 X11

JUNE = 1.79 -8.111E-03 X5 -1.961E-04 X6 +3.992E-06 X15 +5.046E-02 X4 +3.761E-05 X12 -1.80E-05 X14 -2.209E-02 X1 +1.622E-04 X9

JULY = 18.20 +1.625E-05 X11 -4.686E-02 X2 +6.09E-06 X15 +9.928E-04 X6 -2.272E-02 X1 -1.675E-05 X14

AUG. = 9.41 +4.828E-03 X1 +3.074E-05 X11 -3.381E-02 X2 +1.848E-04 X7 +1.449E-03 X8 +9.404E-03 X4 -4.662E-05 X10 +5.393E-06 X15

SEPT. = 5.29 -2.829E-02 X2 +3.181E-04 X7 +4.77E-05 X11 -4.575E-05 X10

OCT. = 1.22 -4.191E-02 X2 +1.142E-02 X1 -8.064E-05 X12

NOV. = -25.48 +4.593E-03 X6 +1.282E-02 X1

DEC. = -31.16 +5.168E-04 X3 + 2.386E-02 X1 -6.403E-06 X15 +1.920E-05 X14

ANN. = 9.30 +6.567E-03 X5

NOTE: See Note on Table 3A

Reg. Eq. for	No. of Obs.	Mult. Corr. Coeff.	Standard Error Deg. C
Jan.	44	0.941	1.5
Feb.	44	0.975	1.3
Mar.	44	0.974	1.3
Apr.	44	0.975	1.3
May	66	0.952	0.9
June	70	0.868	0.8
July	70	0.814	0.8
Aug.	70	0.811	0.7
Sept.	65	0.852	0.7
Oct.	46	0.962	0.8
Nov.	44	0.953	1.4
Dec.	44	0.957	1.3
Ann.	44	0.972	0.8

TABLE 4B

REGION 2/3 - SPATIAL CLIMATIC EQUATIONS FOR MINIMUM DAILY AIR TEMPERATURE NORMALS (BELOW 55° LATITUDE)

JAN. = -37.21 +1.426E-2 X14 +8.434E-2 X5 -1.891E-2 X8

FEB. = -32.71 +2.292E-2 X14 +3.107E-2 X6

MAR. = -27.12 +3.13E-2 X6 -2.911E-2 X8 +5.133E-2 X5

APR. = 8.42 -9.113E-3 X6 +7.709E-4 X10 -3.701E-3 X3 -2.329E-2 X8 -7.824E-2 X2 -1.583E-3 X9

MAY = 16.71 -5.875E-2 X2 -5.047E-3 X4 +4.871E-4 X10 -2.837E-3 X3 -3.269E-2 X1 -6.625E-3 X14

JUNE = 2.31 -3.630E-3 X3 +2.247E-2 X5 +1.227E-2 X6

JULY = 3.44 +1.28E-2 X1 +2.102E-4 X10 -2.953E-3 X3 +1.817E-2 X6

AUG. = 0.95 +1.435E-2 X1 +2.005E-2 X6 -2.304E-3 X3

SEPT. = -0.96 +4.695E-4 X1 +7.361E-3 X6 -2.474E-3 X3 +2.308E-2 X5

OCT. = -3.76 +3.393E-2 X5 -2.972E-2 X13 -1.202E-3 X11 -1.181E-3 X3

NOV. = -18.91 -6.972E-3 X6 +5.757E-2 X5 +1.123E-2 X14 -2.830E-3 X3

DEC. = -13.05 +1.181E-2 X14 -8.393E-2 X2 -1.823E-2 X8

ANN. = -15.28 +3.6316056E-2 X6

NOTE: See Note on Table 3A

Reg. Eq. for	No. of Obs.	Mult. Corr. Coeff.	Standard Error Deg. C
Jan.	277	0.926	1.1
Feb.	277	0.919	1.3
Mar.	277	0.898	1.1
Apr.	281	0.848	0.6
May	305	0.693	0.7
June	313	0.816	0.8
July	313	0.827	0.9
Aug.	313	0.789	0.9
Sept.	307	0.690	0.9
Oct.	297	0.552	1.0
Nov.	280	0.785	0.9
Dec.	280	0.911	1.1
Ann.	277	0.773	0.9

TABLE 5A

REGION 1 - SPATIAL CLIMATIC EQUATIONS FOR PRECIPITATION NORMALS ABOVE 55° LATITUTDE

JAN. = -11.8 +1.22E-02 X5 +8.44E-03 X1 +3.97E-04 X15 -3.36E-04 X10 -7.18E-03 X7

FEB. = -10.4 +1.77E-02 X5 -4.77E-02 X1 -2.48E-05 X14

MAR. = -11.3 +1.66E-02 X5 -2.35E-02 X1 -1.52E-03 X24 -7.93E-01 X28

APR. = -11.5 +6.87E-03 X5

MAY = -11.9 +1.02E-02 X5 +6.04E-04 X3 -1.45E-07 X27

JUNE = 2.1 +1.48E-02 X5 -3.52E-07 X27 -6.38E-02 X25 -5.18E-03 X8

JULY = 26.0 -9.4E-02 X2 -2.93E-07 X27 +6.30E-04 X3 -2.96E-02 X1

AUG. = 3.8 +4.40E-04 X3 -2.55E-07 X27 +1.59E-02 X5 -1.70E-02 X25 -6.42E-03 X6

SEPT. = -2.4 +2.54E-02 X1 -6.50E-04 X3 -2.31E-07 X27 +1.83E-02 X5 -9.54E-03 X6 -8.81E-06 X15

OCT. = 9.1 +1.64E00 X19 -1.90E-04 X32 -3.24E-02 X2 -6.15E-03 X22 -3.86E-03 X23 -2.27E-04 X10 -2.05E-03 X8

NOV. = 9.8 -9.02E-02 X2 +2.60E-05 X15 -1.60E-04 X11 -1.81E-01 X28

DEC. = 29.5 -1.37E-01 X2 -5.03E-02 X1 -2.44E-05 X14

ANN. = 22.3 +1.30E-02 X5 -4.17E-03 X6

NOTE: 1. Read 1.22E-02 X5 as $1.22\ 10^{-2}$X5

2. Dependent variables are Logarithms to the base 10 of precipitation normal in millimeters and physiographic characteristics are in the units indicated in Table 2.

3. The independent variables (physiographic parameters) in the above equations appear in the order they were selected by the Step-wise regression analysis.

Reg. Eq. for	No. of Obs.	Mult. Corr. Coeff.	Standard Error (mm)	Percent
Jan.	50	0.900	3.8	18
Feb.	50	0.918	3.6	18
Mar.	50	0.823	3.8	23
Apr.	52	0.815	3.6	20
May	82	0.931	5.3	16
June	83	0.950	8.9	16
July	83	0.895	10.4	16
Aug.	83	0.884	7.6	13
Sept.	80	0.870	6.9	15
Oct.	54	0.560	4.1	14
Nov.	50	0.797	5.6	20
Dec.	50	0.869	3.8	18
Ann.	50	0.908	39.1	10

TABLE 5B

REGION 2 - SPATIAL CLIMATIC EQUATIONS FOR PRECIPITATION NORMALS FOR THE WESTERN REGION BELOW 55° LATITUDE

JAN. = 4.2 -4.55E-03 X25 +8.13E-03 X7 -5.06E-02 X1 +1.68E-04 X32 -2.00E-03 X17

FEB. = 3.5 -1.22E-03 X8 -4.58E-02 X25 -1.05E-05 X16 +2.14E-05 X15

MAR. = -17.1 +1.31E-03 X3 -5.87E-04 X16 +3.13E-04 X10

APR. = -46.0 -1.28E-02 X3 +2.50E-04 X10 -3.37E-05 X25 +3.61E-03 X11 +6.97E-05 X21

MAY = -8.8 +8.94E-04 X3 +2.54E-02 X29 +6.43E-08 X27 +2.66E-04 X10 -4.43E-06 X16

JUNE = 4.6 +5.13E-04 X3 +2.07E-03 X29 +3.96E-08 X27

JULY = 9.9 -1.25E-03 X16 +1.09E-02 X7 -6.57E-03 X8

AUG. = 12.7 +4.68E-07 X16 -1.36E-03 X24 +5.65E-04 X3 +2.58E-04 X12

SEPT. = 16.6 -1.17E-01 X1 +8.00E-03 X7 +7.09E-05 X20 +2.31E-04 X10 -5.68E-04 X9

OCT. = 15.7 -1.13E-04 X20 -1.26E-02 X6 -4.06E-06 X26 -6.68E-04 X9 +1.09E-02 X5

NOV. = 1.0 -9.10E-06 X16 -3.03E-02 X25 -7.94E-04 X9 +1.75E-04 X10

DEC. = 1.1 -2.51E-02 X25 +2.83E-02 X29 +3.48E-04 X10 +9.13E-05 X20

ANN. = 2.6 -4.11E-06 X16 +1.87E-03 X19 +2.04E-02 X29 +1.07E-04 X20 +1.48E-04 X10 -5.25E-05 X20

NOTE: See Note on Table 5A

Reg. Eq. for	No. of Obs.	Mult. Corr. Coeff.	Standard Error (mm)	Standard Error Percent
Jan.	143	0.654	3.3	16
Feb.	143	0.564	3.3	20
Mar.	143	0.566	3.6	18
Apr.	149	0.735	4.3	15
May	176	0.836	7.6	15
June	178	0.790	9.4	11
July	178	0.902	10.2	16
Aug.	178	0.918	8.2	13
Sept.	176	0.807	5.8	16
Oct.	161	0.761	3.8	18
Nov.	143	0.548	2.5	17
Dec.	143	0.529	3.6	22
Ann.	143	0.802	35.1	9

TABLE 5C

REGION 3 - SPATIAL CLIMATIC EQUATIONS FOR PRECIPITATION NORMALS FOR THE EASTERN REGION BELOW 55° LATITUDE

JAN. = -10.6 +4.94E-02 X1 -9.57E-06 X16 -6.91E-03 X29

FEB. = -3.2 +9.65E-06 X14

MAR. = 4.0 -3.22E-07 X27 -3.93E-02 X2 -4.46E-06 X16

APR. = -2.5 +1.56E-01 X1 -8.84E-03 X8

MAY = 11.8 +2.95E-03 X29 -7.09E-02 X2 -1.73E-07 X27 -4.98E-06 X16

JUNE = -9.88 +1.55E-04 X12 +2.03E-04 X20 +2.41E-02 X1

JULY = 22.2 -6.09E-06 X16 -1.08E-04 X10 -4.49E-03 X5 +6.74E-03 X29

AUG. = 7.1 +1.48E-04 X12 -3.37E-03 X5 -8.38E-06 X16 +3.96E-03 X7 +4.14E-04 X3

SEPT. = 14.6 -2.56E-05 X14 -4.43E-06 X16 +6.82E-04 X20 -1.91E-03 X3

OCT. = 5.7 -3.15E-05 X14 -4.87E-06 X16

NOV. = 2.3 -3.43E-05 X14

DEC. = 7.2 -2.15E-05 X14 -6.25E-06 X16 -1.76E-04 X11

ANN. = 32.3 +8.38E-05 X12 -1.52E-07 X27 -3.80E-06 X16

NOTE: See Note on Table 5A.

Reg. Eq. for	No. of Obs.	Mult. Corr. Coeff.	Standard Error (mm)	Standard Error Percent
Jan.	196	0.507	3.6	18
Feb.	196	0.283	2.8	17
Mar.	196	0.656	3.8	18
Apr.	197	0.753	3.6	14
May	200	0.789	5.6	13
June	200	0.790	7.4	10
July	200	0.770	6.6	10
Aug.	200	0.777	6.6	12
Sept.	200	0.724	5.6	13
Oct.	196	0.783	3.3	14
Nov.	196	0.715	3.8	18
Dec.	196	0.614	3.3	17
Ann.	196	0.843	31.0	7

TABLE 6A

CALIBRATION STATIONS - ERROR OF REGIONAL ESTIMATES FOR MAXIMUM AND MINIMUM DAILY AIR TEMPERATURE NORMALS

	REGION 1						REGION 2/3					
	NO. OF STATN			S.E.	MAX. ERROR		NO. OF STATN			S.E.	MAX. ERROR	
		(+)	(-)	(°C)	(+) (°C)	(-)		(+)	(-)	(°C)	(+) (°C)	(-)
MAX. JAN	44	26	18	1.4	2.2	3.7	277	140	137	0.9	3.3	2.9
MAX. FEB	44	19	25	1.1	2.6	1.7	277	145	132	0.8	2.2	2.3
MAX. MAR	44	23	21	1.3	2.5	2.7	277	136	141	0.7	1.8	1.8
MAX. APR	44	23	21	1.2	1.9	3.7	281	147	134	0.5	1.7	1.7
MAX. MAY	66	36	30	1.3	3.0	4.2	305	153	152	0.4	1.5	1.6
MAX. JUN	70	38	32	1.1	2.4	4.1	313	157	156	0.5	1.3	1.4
MAX. JUL	70	36	34	0.9	2.6	2.8	313	157	156	0.6	1.8	1.5
MAX. AUG	70	34	36	0.7	1.8	1.6	313	164	149	0.6	1.8	1.6
MAX. SEP	65	34	31	0.7	1.4	1.9	307	155	152	0.4	1.5	1.4
MAX. OCT	46	22	24	0.8	1.9	2.5	297	141	156	0.4	1.3	1.3
MAX. NOV	44	24	20	1.3	2.5	3.4	280	133	147	0.4	1.6	1.5
MAX. DEC	44	22	22	1.4	2.7	4.0	280	144	136	0.8	2.6	2.8
MAX. ANL	44	22	22	0.8	1.7	2.1	277	144	133	0.5	1.3	2.3
MIN. JAN	44	22	22	1.5	2.6	2.6	277	140	137	1.1	3.2	3.7
MIN. FEB	44	24	20	1.3	2.1	3.0	277	141	136	1.3	4.2	4.4
MIN. MAR	44	23	21	1.3	2.7	2.9	277	142	135	1.1	3.2	3.4
MIN. APR	44	20	24	1.3	2.3	3.3	281	137	144	0.6	1.8	2.2
MIN. MAY	66	36	30	0.9	2.2	2.8	305	157	148	0.7	1.9	3.2
MIN. JUN	70	32	38	0.8	1.5	2.2	313	165	148	0.8	2.3	4.1
MIN. JUL	70	33	37	0.8	2.3	1.6	313	163	150	0.9	2.2	3.9
MIN. AUG	70	35	35	0.7	1.7	1.6	313	165	148	0.9	2.3	3.9
MIN. SEP	65	33	32	0.7	1.6	1.9	307	157	150	0.9	2.2	3.6
MIN. OCT	46	22	24	0.8	1.7	1.8	297	145	152	1.0	3.3	3.4
MIN. NOV	44	22	22	1.4	2.8	3.1	280	142	138	0.9	2.7	3.2
MIN. DEC	44	20	24	1.3	2.5	2.9	280	136	144	1.1	3.3	3.9
MIN. ANL	44	25	19	0.8	1.9	1.9	277	137	140	0.9	2.8	3.2

TABLE 6B

VALIDATION STATIONS - ERROR OF REGIONAL ESTIMATES FOR MAXIMUM AND MINIMUM DAILY AIR TEMPERATURE NORMALS

	REGION 1						REGION 2/3					
	NO. OF STATN			S.E.	MAX. ERROR		NO. OF STATN			S.E.	MAX. ERROR	
		(+)	(-)	(°C)	(+)	(°C) (-)		(+)	(-)	(°C)	(+)	(°C) (-)
MAX. JAN	6	4	2	1.0	1.7	0.8	33	17	16	0.9	1.8	1.8
MAX. FEB	6	4	2	1.1	2.3	0.9	33	12	21	0.8	1.8	1.8
MAX. MAR	6	3	3	1.5	1.3	2.8	33	13	20	0.7	1.8	1.5
MAX. APR	6	2	4	2.1	0.4	5.2	33	20	13	0.4	0.9	1.3
MAX. MAY	8	1	7	1.5	0.0	4.1	36	20	16	0.5	1.3	1.7
MAX. JUN	8	3	5	0.8	0.8	1.4	38	22	16	0.6	2.4	1.5
MAX. JUL	8	3	5	0.9	0.4	1.9	38	17	21	0.6	1.7	1.5
MAX. AUG	8	4	4	1.0	0.7	2.3	38	21	17	0.7	1.1	2.3
MAX. SEP	8	2	6	1.3	0.2	4.1	38	23	15	0.4	1.2	0.8
MAX. OCT	6	4	2	1.4	0.4	3.3	34	15	19	0.3	0.5	1.1
MAX. NOV	6	3	3	1.3	1.6	2.5	33	13	20	0.4	0.7	1.7
MAX. DEC	6	2	4	1.1	1.8	1.3	33	17	16	0.8	1.3	1.9
MAX. ANL	6	2	4	1.1	0.6	2.3	33	18	15	0.4	0.8	1.2
MIN. JAN	6	4	2	0.8	1.5	0.8	33	15	18	0.8	1.6	1.7
MIN. FEB	6	4	2	0.7	0.8	0.8	33	17	16	1.2	2.2	3.2
MIN. MAR	6	3	3	0.7	0.6	1.4	33	13	20	0.9	1.1	2.4
MIN. APR	6	3	3	2.0	2.2	2.9	33	12	21	0.5	1.1	1.1
MIN. MAY	8	3	5	1.6	0.8	3.7	36	15	21	0.7	1.5	2.0
MIN. JUN	8	4	4	0.7	0.8	1.4	38	16	22	0.7	1.7	2.4
MIN. JUL	8	5	3	0.8	0.8	1.9	38	15	23	0.8	1.3	2.8
MIN. AUG	8	3	5	0.9	0.8	1.8	38	16	22	0.9	1.4	3.2
MIN. SEP	8	5	3	0.6	0.9	0.7	38	17	21	0.9	1.7	2.3
MIN. OCT	6	3	3	1.1	0.6	1.9	34	10	24	0.9	1.7	3.1
MIN. NOV	6	3	3	1.5	1.8	2.3	33	16	17	0.8	1.9	1.9
MIN. DEC	6	2	4	1.1	0.8	2.1	33	13	20	0.9	1.7	2.3
MIN. ANL	6	3	3	1.0	0.6	1.9	33	10	23	0.9	1.4	2.5

TABLE 7

ERROR OF REGIONAL ESTIMATES FOR MAXIMUM AND MINIMUM DAILY AIR TEMPERATURE NORMALS BY LATITUDE

	LAT 49 - 52						LAT 52 - 55					
	NO. OF STATN			S.E. (°C)	MAX.ERROR (°C)		NO. OF STATN			S.E. (°C)	MAX.ERROR (°C)	
	(+)	(-)			(+)	(-)	(+)	(-)			(+)	(-)
MAX. JAN	200	103	97	1.0	3.4	2.9	110	54	56	0.9	1.8	2.0
MAX. FEB	200	105	95	0.8	2.2	2.3	110	52	48	0.8	1.8	1.6
MAX. MAR	200	99	101	0.7	1.8	1.8	110	50	60	0.7	1.9	1.3
MAX. APR	202	110	92	0.6	1.8	1.7	112	57	55	0.6	1.1	1.4
MAX. MAY	204	101	103	0.4	1.5	1.7	137	72	65	0.6	1.3	1.6
MAX. JUN	206	104	102	0.6	1.4	1.5	145	73	70	0.6	2.5	1.4
MAX. JUL	206	105	101	0.6	1.4	1.5	145	69	76	0.4	1.9	1.4
MAX. AUG	206	112	94	0.7	1.2	1.6	145	73	72	0.6	1.3	2.4
MAX. SEP	206	118	88	0.4	1.6	1.4	139	60	79	0.4	1.3	1.3
MAX. OCT	204	94	110	0.4	1.2	1.3	127	62	65	0.4	1.3	1.1
MAX. NOV	202	100	102	0.5	1.2	1.7	111	46	65	0.4	1.6	0.9
MAX. DEC	202	105	97	0.8	2.6	2.8	111	56	55	0.7	1.8	1.4
MAX. ANL	200	108	92	0.5	1.3	1.4	110	54	56	0.6	1.3	2.4
MIN. JAN	200	105	95	1.1	2.4	3.8	110	50	60	1.2	3.2	2.7
MIN. FEB	200	96	104	1.3	2.7	4.4	110	62	48	1.3	4.2	3.2
MIN. MAR	200	103	97	1.1	2.9	3.4	110	52	58	1.1	3.2	2.7
MIN. APR	202	95	107	0.6	1.6	1.4	112	54	48	0.7	1.8	2.2
MIN. MAY	204	104	100	0.7	1.5	2.1	137	68	69	0.9	1.9	3.3
MIN. JUN	206	111	95	0.7	1.6	2.6	145	70	75	1.9	2.3	4.1
MIN. JUL	206	110	96	0.8	1.7	3.2	145	68	77	1.0	2.2	3.9
MIN. AUG	206	109	97	0.9	2.0	3.7	145	72	73	1.1	2.3	3.9
MIN. SEP	206	106	100	0.8	1.8	2.7	139	68	71	1.0	2.3	3.6
MIN. OCT	204	95	109	1.0	2.4	3.4	127	60	67	1.0	3.3	3.3
MIN NOV	202	104	98	0.9	2.2	3.1	111	54	57	0.9	2.7	3.2
MIN. DEC	202	97	105	1.1	2.2	4.0	111	52	59	1.2	3.3	3.7
MIN. ANL	200	94	106	0.9	2.2	3.2	110	53	57	0.9	2.8	2.0

	LAT 55 - 60													
	NO. OF STATN			S.E. (°C)	MAX.ERROR (°C)			NO. OF STATN			S.E. (°C)	MAX.ERROR (°C)		
	(+)	(-)			(+)	(-)		(+)	(-)			(+)	(-)	
MAX. JAN	25	16	9	1.4	2.1	3.8	MIN. JAN	25	13	12	1.5	2.2	2.4	
MAX. FEB	25	12	13	1.1	2.7	1.4	MIN. FEB	25	14	11	1.2	2.1	1.9	
MAX. MAR	25	13	12	1.4	2.5	2.8	MIN. MAR	25	13	12	1.1	2.2	1.8	
MAX. APR	25	15	10	1.5	1.9	5.3	MIN. APR	25	12	13	1.3	2.2	3.3	
MAX. MAY	49	26	23	1.1	2.7	3.1	MIN. MAY	49	27	22	0.9	1.9	2.3	
MAX. JUN	53	30	23	0.8	2.4	1.9	MIN. JUN	53	27	26	0.8	2.0	2.1	
MAX. JUL	53	28	25	0.7	1.7	1.7	MIN. JUL	53	28	25	0.8	2.4	1.6	
MAX. AUG	53	28	25	0.8	1.8	2.3	MIN. AUG	53	26	27	0.8	1.7	1.6	
MAX. SEP	48	23	25	0.9	1.4	4.1	MIN. SEP	48	24	24	0.8	1.6	2.0	
MAX. OCT	27	16	11	1.2	2.0	3.3	MIN. OCT	27	12	15	0.9	1.7	2.0	
MAX. NOV	25	15	10	1.3	2.2	3.4	MIN. NOV	25	14	11	1.2	2.1	2.4	
MAX. DEC	25	12	13	1.5	2.5	4.0	MIN. DEC	25	10	15	1.2	1.8	2.9	
MAX. ANL	25	11	14	0.9	1.7	2.3	MIN. ANL	25	15	10	0.8	1.5	2.1	

TABLE 7 (cont'd)

ERROR OF REGIONAL ESTIMATES FOR MAXIMUM AND MINIMUM AIR TEMPERATURE NORMALS BY LATITUDE

	LAT 60 - 64						LAT 64 - UP					
	NO. OF STATN			S.E.	MAX.ERROR		NO. OF STATN			S.E.	MAX.ERROR	
		(+)	(-)	(°C)	(+)	(°C) (-)		(+)	(-)	(°C)	(+)	(°C) (-)
MAX. JAN	11	5	6	1.4	2.2	2.1	14	9	5	1.4	2.2	2.4
MAX. FEB	11	1	10	0.7	0.6	1.7	14	10	4	1.1	2.4	1.4
MAX. MAR	11	6	5	1.2	1.4	2.3	14	7	7	1.4	1.3	2.7
MAX. APR	11	5	6	1.0	1.8	1.9	14	5	9	1.8	1.9	3.7
MAX. MAY	11	3	8	1.2	1.6	3.3	14	8	6	2.4	3.0	4.2
MAX. JUN	L1	4	7	1.6	2.3	4.1	14	7	7	1.5	1.9	3.0
MAX. JUL	11	4	7	1.4	2.6	2.8	14	7	7	1.1	1.6	2.3
MAX. AUG	11	4	7	0.9	1.8	1.6	14	6	8	0.7	1.1	1.6
MAX. SEP	L1	5	6	0.6	1.2	0.8	14	8	6	0.9	1.1	1.9
MAX. OCT	11	2	9	0.6	0.8	1.3	14	8	6	0.7	1.3	1.1
MAX. NOV	11	4	7	1.3	1.7	2.3	14	8	6	1.5	2.5	2.1
MAX. DEC	11	5	6	1.3	2.7	1.7	14	6	6	1.3	2.2	2.3
MAX. ANL	11	6	5	0.4	0.6	0.9	14	7	7	1.1	1.1	2.2
MIN. JAN	11	5	6	1.4	2.3	2.2	14	8	6	1.7	2.7	2.6
MIN. FEB	11	5	6	1.3	1.0	3.0	14	9	5	1.4	2.1	2.2
MIN. MAR	11	5	6	1.3	0.8	2.9	14	8	6	1.5	2.7	2.3
MIN. APR	11	5	6	1.6	2.3	2.1	14	6	8	1.6	2.2	3.0
MIN. MAY	11	5	6	0.8	0.8	1.5	14	7	7	1.6	2.2	3.7
MIN. JUN	11	3	8	1.1	1.7	1.7	14	6	8	0.9	1.2	2.3
MIN. JUL	11	4	7	0.9	1.7	1.6	14	6	8	0.9	1.0	1.9
MIN. AUG	11	6	5	0.8	1.2	1.7	14	6	8	0.8	0.7	1.9
MIN. SEP	11	6	5	0.6	0.9	1.1	14	8	6	0.8	1.6	1.1
MIN. OCT	11	6	5	0.8	1.4	0.9	14	7	7	0.9	1.4	1.4
MIN. NOV	11	5	6	1.3	1.9	1.7	14	6	8	1.9	2.8	3.2
MIN. DEC	11	5	6	1.4	2.6	1.7	14	7	7	1.4	2.3	2.7
MIN. ANL	11	5	6	0.6	0.8	1.1	14	8	6	1.1	2.0	1.9

TABLE 8A

CALIBRATION STATIONS - ERRORS OF REGIONAL ESTIMATES FOR PRECIPITATION NORMALS

	REGION 1					REGION 2					
	NO. OF STATN	(+)	(-)	S.E. (mm)	MAX.ERROR (+) (mm)	(-)	NO. OF STATN	(+)	(-)	S.E. (mm)	MAX.ERROR (+) (mm)	(-)
PREC. JAN	50	31	19	3.8	8.4	8.6	143	75	68	3.3	16.8	7.9
PREC. FEB	50	26	24	3.6	9.4	6.1	143	78	65	3.3	9.1	9.9
PREC. MAR	50	27	23	3.8	14.0	5.1	143	72	71	3.6	17.0	9.7
PREC. APR	52	33	19	3.6	12.7	8.9	149	77	72	4.8	14.2	32.5
PREC. MAY	82	43	39	5.3	17.3	10.2	176	95	81	7.6	22.4	22.4
PREC. JUN	83	42	41	8.9	22.9	18.0	178	100	78	9.4	50.5	19.8
PREC. JUL	83	49	34	10.4	38.6	16.0	178	95	83	10.2	45.7	39.1
PREC. AUG	83	43	40	7.6	24.4	17.8	178	98	80	8.1	28.2	22.9
PREC. SEP	80	45	35	6.9	28.7	11.2	176	91	85	5.8	26.4	10.7
PREC. OCT	54	30	24	4.1	10.4	7.6	161	81	80	3.8	17.8	10.2
PREC. NOV	50	23	27	5.6	17.0	13.2	143	76	67	2.5	8.9	7.1
PREC. DEC	50	24	26	3.8	10.7	6.4	143	78	65	3.6	15.2	8.4
PREC. ANL	50	27	23	39.1	110.2	76.2	143	66	77	35.1	131.8	98.8

	REGION 3					
	NO. OF STATN	(+)	(-)	S.E. (mm)	MAX. ERROR (+) (mm)	(-)
PREC. JAN	196	103	93	3.6	11.7	7.1
PREC. FEB	196	106	90	2.8	14.0	6.4
PREC. MAR	196	99	97	3.8	21.3	9.9
PREC. APR	197	98	99	3.6	10.4	7.8
PREC. MAY	200	104	96	5.6	30.7	17.3
PREC. JUN	200	103	97	7.4	32.8	29.2
PREC. JUL	200	101	99	6.6	22.4	19.3
PREC. Aug.	200	99	101	6.6	20.1	24.4
PREC. SEP.	200	112	88	5.6	31.2	11.6
PREC. OCT.	197	109	88	3.3	10.9	11.2
PREC. NOV.	196	101	95	3.8	14.7	9.4
PREC. DEC.	196	94	102	3.3	12.2	8.4
PREC. ANL.	196	101	95	31.0	110.4	93.7

TABLE 8B

VALIDATION STATIONS - ERROR OF REGIONAL ESTIMATES FOR PRECIPITATION NORMALS

	REGION 1						REGION 2					
	NO. OF STATN			S.E.	MAX.ERROR		NO. OF STATN			S.E.	MAX.ERROR	
		(+)	(-)	(mm)	(+)	(mm) (-)		(+)	(-)	(mm)	(+)	(mm) (-)
PREC. JAN	6	2	4	3.3	3.8	5.6	13	7	6	5.1	4.3	14.7
PREC. FEB	6	2	4	2.5	1.3	4.6	13	9	4	5.6	6.4	16.3
PREC. MAR	6	4	2	3.0	3.6	4.6	13	9	4	5.3	5.6	11.7
PREC. APR	6	2	4	4.3	6.1	5.6	14	7	7	5.3	10.7	9.9
PREC. MAY	8	3	5	5.8	11.4	7.4	17	10	7	6.1	16.3	8.4
PREC. JUN	8	5	3	11.9	20.1	17.8	20	11	9	14.5	47.5	21.8
PREC. JUL	8	6	2	7.9	15.5	7.6	20	13	7	13.7	32.8	13.7
PREC. AUG	8	3	5	7.4	7.6	14.5	20	12	8	9.1	15.0	25.9
PREC. SEP	8	3	5	8.2	5.1	16.0	20	11	9	8.9	20.8	10.9
PREC. OCT	7	3	4	4.1	3.6	8.9	13	4	9	2.8	6.4	6.6
PREC. NOV	6	2	4	3.3	2.3	6.1	13	8	5	4.6	7.1	11.4
PREC. DEC	6	1	5	3.3	2.3	7.6	13	7	6	3.8	6.1	6.6
PREC. ANL	6	1	5	39.9	33.3	87.6	13	6	7	56.6	66.5	108.2

	REGION 3					
	NO. OF STATN			S.E.	MAX.ERROR	
		(+)	(-)	(mm)	(+)	(mm) (-)
PREC. JAN	21	8	13	3.3	8.9	4.8
PREC. FEB	21	12	9	2.5	4.8	7.1
PREC. MAR	21	10	11	4.3	8.9	9.1
PREC. APR	21	12	9	3.0	7.6	7.4
PREC. MAY	21	8	13	3.8	7.6	9.1
PREC. JUN	21	8	13	6.1	14.2	11.7
PREC. JUL	21	8	13	6.6	13.7	13.0
PREC. AUG	21	9	12	8.4	8.6	19.3
PREC. SEP	21	5	16	3.0	4.3	6.4
PREC. OCT	21	10	11	3.0	7.1	7.6
PREC. NOV	21	9	12	2.8	6.6	4.8
PREC. DEC	21	11	10	3.2	5.6	7.6
PREC. ANL	21	9	12	21.6	26.7	53.6

TABLE 8C

ERROR OF REGIONAL ESTIMATES FOR PRECIPITATION NORMALS BY LATITUDE

	LAT 49 - 52						LAT 52 - 55					
	NO. OF STATN			S.E.	MAX.ERROR		NO. OF STATN			S.E.	MAX.ERROR	
		(+)	(-)	(mm)	(+) (mm)	(-)		(+)	(-)	(mm)	(+) (mm)	(-)
PREC. JAN	235	133	122	3.6	16.8	14.7	118	60	58	3.3	9.9	7.9
PREC. FEB	255	140	115	3.3	14.0	16.3	118	65	53	2.8	8.6	7.1
PREC. MAR	255	134	121	4.1	21.3	11.7	118	56	62	3.0	10.4	8.9
PREC. APR	261	133	128	4.3	12.2	32.5	120	61	59	3.8	14.2	9.4
PREC. MAY	264	137	127	5.8	30.7	22.4	150	80	70	7.4	22.4	17.3
PREC. JUN	265	143	122	7.6	32.8	19.8	154	79	75	10.2	50.5	29.2
PREC. JUL	265	134	131	7.4	45.7	16.3	154	83	71	10.7	32.8	39.1
PREC. AUG	265	127	138	6.4	19.8	21.4	154	91	63	8.9	28.2	25.9
PREC. SEP	264	143	121	4.6	26.4	10.7	153	76	77	7.6	31.2	11.7
PREC. OCT	259	140	119	3.1	13.7	7.6	133	64	69	4.1	17.8	11.2
PREC. NOV	255	130	125	3.3	14.7	11.4	118	64	54	3.0	12.5	6.4
PREC. DEC	255	127	128	3.6	15.2	8.4	118	63	55	3.3	12.2	5.6
PREC. ANL	255	125	130	35.1	131.8	108.2	118	57	61	29.5	85.9	93.7

	LAT 55 - 60					
	NO. OF STATN			S.E.	MAX.ERROR	
		(+)	(-)	(mm)	(+) (mm)	(-)
PREC. JAN	31	21	10	4.1	8.4	8.6
PREC. FEB	31	14	17	3.8	9.4	5.8
PREC. MAR	31	18	13	3.6	13.7	4.8
PREC. APR	33	22	11	3.8	9.7	8.9
PREC. MAY	65	37	28	5.8	17.3	9.6
PREC. JUN	66	35	31	10.4	22.9	18.0
PREC. JUL	66	42	24	10.6	38.6	16.0
PREC. AUG	66	35	31	8.6	24.4	17.8
PREC. SEP	63	37	26	7.9	28.7	16.0
PREC. OCT	36	17	19	3.6	8.4	6.9
PREC. NOV	31	14	17	4.6	11.2	8.9
PREC. DEC	31	13	18	4.1	10.7	6.4
PREC. ANL	31	18	13	37.1	63.2	65.3

TABLE 8C (cont'd)

ERROR OF REGIONAL ESTIMATES FOR PRECIPITATION NORMALS BY LATITUDE

	LAT 60 - 64						LAT 64 - UP					
	NO. OF STATN			S.E.	MAX. ERROR		NO. OF STATN			S.E.	MAX. ERROR	
		(+)	(-)	(mm)	(+)	(mm) (-)		(+)	(-)	(mm)	(+)	(mm) (-)
PREC. JAN	11	5	6	3.0	2.8	6.6	14	7	7	3.6	8.1	5.6
PREC. FEB	11	5	6	2.5	2.0	6.1	14	9	5	3.0	8.4	4.6
PREC. MAR	11	5	6	2.0	2.2	5.1	14	8	6	4.8	14.0	4.6
PREC. APR	11	5	6	2.8	5.1	3.6	14	8	6	4.3	12.7	5.6
PREC. MAY	11	3	8	5.3	9.1	6.4	14	6	8	3.3	6.9	5.1
PREC. JUN	11	3	8	4.1	4.8	7.4	14	9	5	5.1	13.0	11.2
PREC. JUL	11	3	8	7.4	9.4	16.0	14	10	4	6.9	12.2	10.4
PREC. AUG	11	4	7	4.6	5.6	7.9	14	7	7	4.8	8.9	5.6
PREC. SEP	11	4	7	5.1	7.9	7.1	14	7	7	5.6	10.9	11.9
PREC. OCT	11	9	2	3.6	6.6	6.4	14	7	7	5.1	10.4	8.9
PREC. NOV	11	3	8	3.6	14.7	13.2	14	8	6	5.6	17.0	5.8
PREC. DEC	11	5	6	3.0	6.4	4.3	14	7	7	4.3	8.1	7.6
PREC. ANL	11	1	10	24.4	2.8	76.2	14	9	5	49.8	110.2	87.6

TABLE 9

LOCATION, PHYSIOGRAPHIC CHARACTERISTICS AND CLIMATIC DATA FILE RECORD LAYOUT

CHARACTER	IDENTIFICATION	UNIT	FORTRAN FORMAT
1-3	Column Number of Grid Square	-	I3
4-6	Row Number of Grid Square	-	I3
7-14	U.T.M. Grid Square Location	-	A8
15-22	U.T.M. Easting	-	I8
23-29	U.T.M. Northing	-	I7
30-33	U.T.M. Zone	-	A4
34-37	Longitude of grid square center	degrees	I4
38-39	Longitude " " " "	minutes	I2
40-42	Latitude " " " "	degrees	I3
43-44	Latitude " " " "	minutes	I2
45-50	X-coordinate (Lambert Conformal 1:1 mill. proj.	inches	F6.2
51-56	Y- " " " " " "	inches	F6.2
57-62	X- "" " " 1:5 " "	inches	F6.2
63-68	Y- " " " " " "	inches	F6.2
69-72	Area of Square	percent	I4
73-76	Area of Sea	percent	I4
77-80	Area of Lakes	percent	I4
81-84	Area of Forest	percent	I4
85-88	Area of Bogs and Swamp	percent	I4
89-92	Area of Glaciers	percent	I4
93-96	Area of Built Up Areas	percent	I4
97-100	Elevation of S.W. Corner of Grid Squar	m	I4
101-104	Average Elevation of Grid Square	m	I4
105-108	Slope of Grid Square	$m/10^4 m$	I4
109-112	Azimuth of Slope	degrees	I4
113-116	Pointer for Square in area	-	I4
117-120	Distance to Sea in North Direction	km x 10	I4
121-124	" " " " N.W. "	km x 10	I4
125-128	" " " " West "	km x 10	I4
129-132	" " " " S.W. "	km x 10	I4

TABLE 9 (cont'd)

LOCATION, PHYSIOGRAPHIC CHARACTERISTICS AND CLIMATIC DATA FILE RECORD LAYOUT

CHARACTER	IDENTIFICATION	UNIT	FORTRAN FORMAT
133-136	Barrier Height in North Direction	m	I4
137-140	" " " N.W. "	m	I4
141-144	" " " West "	m	I4
145-148	" " " S.W. "	m	I4
149-152	Shield Factor in the North Direction	m x 100	I4
153-156	" " " " N.W. "	m x 100	I4
157-160	" " " " West "	m x 100	I4
161-164	" " " " S.W. "	m x 100	I4
165-168	Regional Slope in the N.E. Direction	$m/10^3 m$	I4
169-172	" " " " South "	$m/10^3 m$	I4
173-176	" " " " S.E. "	$m/10^3 m$	I4
177-180	Estimated Average January Maximum Daily Temp.	^oC x 10	I4
181-184	" " February " " "	^oC x 10	I4
185-188	" " March " " "	^oC x 10	I4
189-192	" " April " " "	^oC x 10	I4
193-196	" " May " " "	^oC x 10	I4
197-200	" " June " " "	^oC x 10	I4
201-204	" " July " " "	^oC x 10	I4
205-208	" " August " " "	^oC x 10	I4
209-212	" " September " " "	^oC x 10	I4
213-216	" " October " " "	^oC x 10	I4
217-220	" " November " " "	^oC x 10	I4
221-224	" " December " " "	^oC x 10	I4
225-228	" " Annual " " "	^oC x 10	I4
229-232	Estimated Average January Minimum Daily Temp.	^oC x 10	I4
233-236	" " February " " "	^oC x 10	I4
237-240	" " March " " "	^oC x 10	I4
241-244	" " April " " "	^oC x 10	I4
245-248	" " May " " "	^oC x 10	I4

TABLE 9 (cont'd)

LOCATION, PHYSIOGRAPHIC CHARACTERISTICS AND CLIMATIC DATA FILE RECORD LAYOUT

CHARACTER	IDENTIFICATION	UNIT	FORTRAN FORMAT
249-252	Estimated Average June Minimum Daily Temp.	$^{o}C \times 10$	I4
253-256	" " July " " "	$^{o}C \times 10$	I4
257-260	" " August " " "	$^{o}C \times 10$	I4
261-264	" " September " " "	$^{o}C \times 10$	I4
265-268	" " October " " "	$^{o}C \times 10$	I4
269-272	" " November " " "	$^{o}C \times 10$	I4
273-276	" " December " " "	$^{o}C \times 10$	I4
277-280	" " Annual " " "	$^{o}C \times 10$	I4
281-284	Estimated Average January Precipitation	mm	I4
285-288	" " February "	mm	I4
289-292	" " March "	mm	I4
293-296	" " April "	mm	I4
297-300	" " May "	mm	I4
301-304	" " June "	mm	I4
305-308	" " July "	mm	I4
309-312	" " August "	mm	I4
313-316	" " September "	mm	I4
317-320	" " October "	mm	I4
321-324	" " November "	mm	I4
325-328	" " December "	mm	I4
329-332	" " Annual "	mm	I4

*Note: There are 18 files corresponding to the 1:1 million NTS Topographic Sheets Listed in Table 10.

TABLE 10

LISTING OF THE NATIONAL TOPOGRAPHIC SYSTEM
OF CANADA 1:1 MILLION SCALE MAP SHEETS
CORRESPONDING TO THE DATA FILES
COVERING THE CANADIAN GREAT PLAINS

File No.	NTS Identification	Name	Geographical Area Contained Within By Latitude and Longitude			
			Latitude		Longitude	
			North	South	West	East
1	NM-11	Kootenay Lake	52°	49°	120°	114°
2	NM-12	Lethbridge	52°	49°	114°	108°
3	NM-13	Regina	52°	49°	108°	102°
4	NM-14	Winnipeg	52°	49°	102°	96°
5	NN-10	Prince George	56°	52°	126°	120°
6	NN-11	Lessor Slave Lake	56°	52°	120°	114°
7	NN-12	Edmonton	56°	52°	114°	108°
8	NN-13	Prince Albert	56°	52°	108°	102°
9	NN-14	The Pas	56°	52°	102°	96°
10	NO-10	Fort Nelson	60°	56°	126°	120°
11	NO-11	Peace River	60°	56°	120°	114°
12	NO-12	Lake Athabasca	60°	56°	114°	108°
13	NP9/10	Redstone River	64°	60°	128°	120°
14	NP11/12	Slave River	64°	60°	120°	114°
15	NQ7/8/9	Peel River	68°	64°	144°	128°
16	NQ9/10/11/12	Great Bear River	68°	64°	128°	112°
17	NR7/8/9	Firth River	72°	68°	144°	128°
18	NR9/10/11/12	Horton River	72°	68°	128°	112°

*Note: Records contained within each map file pertain to the area occupied by the Canadian Great Plains only.